IDENTIFICATION AND ANALYSIS OF AQUATIC AND RIPARIAN HABITAT IMPAIRMENT ASSOCIATED WITH DAMS OF THE VIRGINIA TIDEWATER REGION

Submitted by:

Dr. Stephen P. McIninch
Dr. Greg C. Garman
Center for Environmental Studies and
Department of Biology
Virginia Commonwealth University
Richmond, Virginia 23284-2012

30 April 2000

Proper Citation: McIninch, S.P. and G.C. Garman. 2000. Identification and analysis of aquatic and riparian habitat impairment associated with dams of the Virginia Tidewater region. Final Project Report to Virginia Department of Conservation & Recreation, Richmond, VA.

This report was 55% funded by the Virginia Department of Conservation and Recreation in coordination with the National oceanic and Atmospheric Administration.

Summary

- The goal of this study was to develop an accurate and comprehensive database for dams in the Tidewater region of Virginia and contribute to the evaluation of potential habitat degradation below these existing dams.

- Specific objectives for Phase I were 1) develop an accurate, current, dam database for Tidewater Virginia, 2) develop a process for the quantitative evaluation of potential habitat degradation below existing dams, and 3) present recommendations on how to identify problems and potential opportunities for improvement of habitat.

- We documented location and status of 499 dams and measured habitat characteristics of a statistically valid number of tributaries in Tidewater, Virginia. In addition, a series of statistical analyses were performed to assess the quantitative and qualitative habitat variables collected in reference to hydromodification characteristics.

- The statistical approach of our study was designed 1) to identify potential degradations of habitat due to dam maintenance and operation, and 2) to determine if certain attributes (classes) of the dams could be linked to a specific type of degradation.

- Results of the Canonical Correspondence Analysis show a clear separation of sites across the first two canonical axes. The first horizontal axis represents a gradient of both substrate and riparian characteristics. The second axis is the vertical axis and represents a gradient of habitat, water quality, and stream morphology characteristics.

- Impounded streams of the Tidewater region do exhibit degraded conditions when compared to reference conditions. These differences are reflected in the overall habitat evaluation scores (Higher scores in reference conditions), but individually in few parameters.

- This study presents opportunities for restoration of instream habitats (specifically substrate and channel morphometry), riparian habitats (to aid restoration of reduced canopies), and biological components of the stream ecosystem (through dam removal and fish passage).

Identification and Analysis of Aquatic and Riparian Habitat Impairment Associated with Dams of the Virginia Tidewater Region.

Introduction

Section 6217 of the reauthorized Coastal Zone Management Act (1990) contains provisions that require states with federally approved coastal resources management programs to develop coastal nonpoint source pollution control programs to address sources of Nonpoint Source (NPS) pollution, which degrade water quality of Coastal Plain tributaries. In 1993, a guidance document was released by the U.S. Environmental Protection Agency (EPA) to assist in developing nonpoint source pollution control programs [Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, EPA-840-B-92-001c]. The Commonwealth of Virginia responded to the federal mandate by developing the Coastal Nonpoint Source Pollution Control Program Submittal [Department of Conservation & Recreation, September 1995]. The National Oceanic and Atmospheric Administration (NOAA) and EPA reviewed the control program and released findings in July, 1998. Most recently, the Commonwealth of Virginia has completed the Nonpoint Source Pollution Management Program [Department of Conservation & Recreation, December 1999]. One potential source of nonpoint source pollution addressed in all of these documents is that produced by hydromodification.

Hydromodification includes channelization and channel modification, dams, and streambank and shoreline erosion. Generally, there are three potential sources of nonpoint pollution and habitat impairment under this heading: 1) dams, both new construction and existing structures, 2) excessive surface water withdrawals associated with existing dams, and 3) dredging and channel modification activities. The NOAA and EPA findings identified a few management areas where the Virginia program may be deficient, according to Section 6217 (g) guidance. “Virginia’s program does not include: (1) a process to improve surface water quality and restore instream and riparian habitat through the operation and maintenance of existing modified channels; (2) management measures to manage the operation of dams to protect surface water quality and instream and riparian habitat and to assess nonpoint source problems resulting from excessive surface water withdrawals; (3) management measures for chemical control at dams; and (4) a process to identify and develop strategies to solve existing nonpoint source problems caused by streambank or shoreline erosion that do not come up for review under existing permit authorities.” These issues are mostly concerned with existing structures but DCR presently lacks a system for the identification and assessment of potential problems (i.e. habitat impairment) associated with hydromodification activities.

The goal of this study was to develop an accurate, and comprehensive database for dams in the Tidewater region of Virginia and contribute to the evaluation of potential habitat degradation below these existing dams. This study represents Phase I of a larger grant to investigate the many forms of hydromodification in the Tidewater region and their impact on instream and riparian habitats.

OBJECTIVES

The specific objectives of the Phase I study were:

1. **Develop an accurate, current, dam database for Tidewater Virginia.**
2. **Develop a process for the quantitative evaluation of potential habitat degradation below existing dams.**
3. **Present recommendations on how to identify problems and potential opportunities for improvement of habitat.**

METHODS

Project Approach

We documented location and status of about 500 dams and measured habitat characteristics of a statistically valid number of tributaries in Tidewater, Virginia. In addition, a series of statistical analyses were performed to assess the quantitative and qualitative habitat variables collected in reference to hydromodification characteristics. We examined how the operation and maintenance of dams affect instream and riparian living resource habitat, and identified opportunities for the restoration of degraded habitats.

Hydromodification Database

The initial survey of dams on waters of the Tidewater region of Virginia was conducted using existing remote data sources such as Virginia Department of Conservation & Recreation (DCR) dam database (K. Huber, unpublished), university impediment databases (Virginia Commonwealth University (VCU) unpublished), existing databases of Virginia Department of Environmental Quality (DEQ), topographic maps (1:24,000), aerial photographs, Federal Energy Regulatory Commission (FERC) surveys of lowhead dams, and digital orthophoto basemaps (1:12,000). Some of these sources were available in Geographic Information System (GIS) format from local, state and federal agencies and were accessed from VCU's GIS facility (www.vcu.edu/CESWEB/). These datasets were examined to develop an accurate, comprehensive database of those dams that exist in Tidewater Virginia and that meet NOAA/EPA definitions and characterizations under Section 6217. For this study, dams are characterized as "constructed impoundments that are either (1) 25 feet or more in height *and* greater than 15 acre-feet in capacity, or (2) 6 feet or more in height *and* greater than 50 acre-feet in capacity (EPA 1993).

From the dam database, thirty-two study sites were chosen and evaluated on-site for the status of each dam, the specific location coordinates, pertinent characteristics (e.g. condition, size, type, etc.), and photographed (Table 1). Location coordinates were established using a Trimble GPS unit and post processed using Geo Explorer software and the assistance and base files of Harry Berquist (College of William & Mary, Virginia Institute of Marine Science). Ten additional sites, without impediments, were chosen as representative of reference conditions or control sites (Table 1).

Habitat assessment

Through quantitative habitat analysis, we developed a database that allowed for the scientific evaluation of specific impairments of downstream habitats. Selected habitat attributes were directly or indirectly related to the quality of fish and wildlife habitat in those areas below impoundments. The purpose was to identify specific habitat impairments that may be associated with one or more types of hydromodification and to quantify the degree of such impairments. Those identified impairments were then scrutinized in order to identify opportunities for habitat restoration.

We selected study sites from the hydromodification database using a stratified random sampling design. Strata used to classify potential sites included 1) major drainage, 2) impoundment age, 3) height of dam, 4) class of dam, and 5) capacity of the impoundment. Stream order, link metric and downstream link metrics were noted to assess placement of the stream reach in the given watershed.

A power analysis (Link and Hatfield 1990, Cohen 1988) was used to estimate the number of study sites needed to obtain a statistically valid sample of sites to assess variable habitat conditions. The analysis suggested 28 samples would be sufficient. We chose 35 experimental sites and included 10 reference (control) sites for comparative purposes. The forty-five sites were chosen at random using a stratified design. Reference streams were selected to correspond to streams of similar size and placement in the watershed as those impounded streams examined (study sites). Three of the 35 experimental sites were omitted following site-visits due to recent removal of two of the dams and large amounts of beaver activity masking habitat alteration at the third location. The final 42 study sites are representative of the various categories of dams of various ages, heights, and capacities in Tidewater tributaries of Virginia (Table 1).

Site visits were made during the period November, 1999 – March, 2000. Habitat variables examined included physiographic parameters (e.g. stream order; link magnitude measures), physico-chemical parameters (e.g. pH; conductivity, temperature, turbidity, channel dimensions; flow characteristics), structural attributes (e.g. substrate composition; large woody debris) and assessment of riparian habitat and stream cover. The habitat assessment protocol followed EPA's rapid habitat assessment protocol (Barbour et al. 1999; Appendix I). In addition to the rapid assessment sheets used (Fig. 1), we also assessed/measured physical habitat and water quality parameters of the stream (Fig. 2).

Physiographic parameters were determined using 7.5-minute topographic maps and ESRI ArcView (ver. 3.1) software. Water quality measures such as pH and dissolved oxygen were measured on-site using calibrated meters. Turbidity was measured using a Texas Instruments Nephelometric turbidimeter and flow was measured using a Marsh-McBirney current meter. Width and depth characteristics of wadable streams were measured at three points corresponding roughly to transects at 25 m, 50 m, and 100 m below the dam. We estimated visually the substrate type and cover over the reach of the stream that was assessed for habitat conditions.

Data Analysis

Statistical analyses were performed using SPSS® and CANOCO® software. All habitat data was examined initially for outliers and normalcy of distribution. Normalcy was tested using the Kolmogorov-Smirnov Test (SPSS®) or Proc Univariate procedures of SAS®. Outliers were examined for accuracy and those variables not exhibiting normal distributions were transformed using appropriate transformations for linear analysis. Data for percentages of habitat parameters in the habitat database was transformed using an arc-sine transformation (Sokal and Rohlf 1987).

Following descriptive statistical analysis, the data were subjected to a series of direct gradient analyses (Canonical Correspondence Analysis; CCA) to explore the relationship, if any, between habitat information collected at impounded and reference sites. Canonical correspondence analysis was used to ordinate the data into two dimensions while concurrently executing a multiple regression analyses of the habitat characteristics (Jongman et al. 1988, Ter Braak 1988).

We used the CCA analysis to examine how sites ordinated along the environmental gradients (habitat variables) tested. The null hypothesis was that there is no grouping(s) of sites within the Tidewater region of Virginia. These analyses supply information about how a range of stream sites (impounded or not) are grouped within Tidewater and allow an initial insight into potential relations with the environmental variables examined. A Monte Carlo test was executed to test the statistical significance of the first resultant axis from the CCA (Ter Braak 1988). We used a null model and 99 iterations of the Monte Carlo examination. Level of significance was set at 0.01 for the Monte Carlo test; for all other statistical analyses the level was 0.05.

Additional statistical analyses, including independent t-tests, linear regressions and Mann-Whitney tests were performed on the habitat dataset. Levene's test for equality of variances was used to assess variances between the experimental group (impounded streams) and control group (reference streams); habitat variables not meeting the assumptions of normality or showing unequal variance between groups were subjected to Mann-Whitney tests (George and Mallery 1999). Remaining variables were analyzed to assess differences in habitat components between the experimental and control groups using the t-test for equality of means.

Linear regressions and the nonparametric Kruskal-Wallis test were used to test for relationships between the dam attributes and habitat variables. For example, we examined if there was a significant relationship between age of dam and amount of riffles habitat in those sites examined. For purposes of these analyses, references sites were given ages of 500 years, dam heights of zero, capacities of zero, and were classed as group 5 of five groups.

Results

Hydromodification Database

Approximately 500 constructed impoundments met the criteria to be designated as a dam. The dam database has been modified in places, corrections made and updated information (for example recent GPS coordinates) have been added. There are 53 fields of information that are explained in the data dictionary (Appendix II).

Habitat Assessment

Study sites selected and reference streams examined are listed in Table 1. The classes of sites used for the stratified sampling were as follows:

CATEGORY	group I	II	III	IV	V
Drainages	Potomac	Rappahannock	York	James	Other
Age of Dam	Pre-1901	1901-1949	1950-1969	1970-present	
Class	1 (run-of-the-river)	2 (mainstem)	3 (transitional)	4 (storage)	
Height	5-15 feet	16-35 ft.	36-80 ft.	> 80 ft.	
Capacity	0-99 acre-ft	100-499 ac-ft	500-2.5K ac-ft	>2,500 ac-ft.	

Results of the Canonical Correspondence Analysis show a clear separation of sites across the first two canonical axes. The first axis was found to be statistically significant ($P>0.01$; Monte Carlo simulation), and we therefore reject our null hypothesis and here simply point out that the distribution of habitat variables across sites from Tidewater are not distributed randomly. Because of the large amount of geographic coverage in the Commonwealth, this is not a dramatic finding.

Figures 3-7 are plots of the first two canonical axes resulting from the canonical correspondence analysis. The Virginia identification number of the dam (see Table 1) represents study sites and control/reference sites are given numbers C1-C10. The first horizontal axis represents a gradient (moving right to left as one looks at the plot) of both substrate and riparian characteristics (Fig. 3, Table 2). Positive correlations (right side of plot) were found with high amounts of riparian vegetation and high amounts of sand and silt as instream substrates. Negative correlations (left side of plot) were highest with variables describing stream size (high widths, depths, and link values) as well as the gravel substrate variable (Table 2).

The second axis is the vertical axis and represents a gradient (moving top to bottom as one looks at the plot) of habitat, water quality, and stream morphology characteristics. Positive correlations (upper portion of plot) are noted with the amount of run habitat, placement in the lower portions of the watershed, and high amounts of riparian vegetation. Negative correlations include stream size attributes (width and depth), pool habitat variability, and pH (Table 2). Those sites located toward the origin (center of the plot), indicate no strong alignment with any of the environmental variables tested.

Figures 3-7 are the same plot with symbols to show placement of the various classes of sites among the quadrants. Fig 3, shows the distribution of drainages in the plot, Fig. 4, the construction year, Fig. 5, the height of the dam, Fig. 6, the capacity of the impoundment, and Fig 7 the class. Because of printing restrictions, some of the study sites are hidden behind those plotted. The CCA resulted in a plot that shows that the sites tested differ from one another based on their characteristics and habitat parameters. These data however do not exhibit a clear separation between reference and experimental groups or based on the dam attributes used to classify the impoundments.

The next step in our data analysis was to perform more direct, and powerful, examinations of potential difference between experimental and control groups. Results of the linear regressions, t-tests, and nonparametric (Mann-Whitney, Kruskal-Wallis) analyses are presented in Tables 3 and 4.

There was a statistically significant difference between the total habitat evaluation scores of experimental and reference sites ($P=0.001$). The follow-up analysis examined the relationship between the various class of variables with total habitat evaluation score. The only class found to be statistically significant from random ($P< 0.001$) was the age of the impoundment: a direct, positive relationship with age of impoundment and habitat evaluation score.

Each of the rapid habitat assessment parameters was next analyzed individually. Those metrics that showed significant differences between experimental and reference sites include those that evaluate the extent of riparian vegetation, the three metrics evaluating stream channel morphometry (flow, alteration, and sinuosity; Appendix I), the variability of pool habitats, and the extent of instream sediment deposition (Table 3). None of the habitat assessment variables were significantly different among sites of different aged impoundment, different capacities, heights, or classes (Table 4).

The analysis of additional habitat parameters including those representing instream morphological features (amount of riffle, run and pool habitat), water quality parameters and substrate composition attributes are listed in Table 3. None of the water quality parameters measured (temperature, turbidity, pH, dissolved oxygen, and conductivity) were significantly different between experimental and control sites. Likewise, flow velocity, stream depth and stream width were the same between the two groups of streams. The proportions of riffle, run and pool habitat did not differ between experimental and control sites nor was there any statistically significant variation in these habitat parameters among sites based on the dam classes tested (age of dam, etc., Table 4).

Substrate composition exhibited significant differences between experimental and control groups, but only for the amount of sand substrate ($P=0.031$) and marl substrate ($P=0.022$). The extent of canopy over the stream exhibited a significant difference between experimental and references streams ($P=0.006$). The extent of canopy cover was found to be significantly different among sites of different impoundment ages ($P=0.002$) and dam heights ($P<0.001$) but not for dam class or impoundment capacity.

Discussion and Recommendations

Instream and riparian habitats were assessed from areas below impoundments located within the Tidewater region of Virginia. We used the U.S. Environmental Protection Agency's Rapid Habitat Assessment protocol as one form of habitat evaluation. Additional quantitative habitat information on substrate, stream morphometry, and water quality was collected. These data were subjected to exploratory analyses in the form of direct gradient analyses and then to more direct comparative analyses.

The statistical approach of our study was designed 1) to identify potential degradation of habitat due to dam maintenance and operation, and 2) to determine if certain attributes (classes) of the dams could be linked to a specific type of degradation. The impounded streams of the Tidewater region exhibit degraded conditions when compared to those reference streams examined. These differences are reflected in the overall habitat evaluation scores (Higher scores in reference conditions), but individually in few parameters. Of the parameters evaluated only three could be shown to be correlated with attributes of the dam. Two of these (extents of canopy and Total habitat score) were found to have positive relationships with age of the dam.

The two substrate characteristics found to be significantly different between experimental and control groups were amount of sand and marl. Marl was not commonly found during this study and was most commonly observed where plunge pools from spillover had scoured substrates. The significant differences of three rapid habitat assessment metrics pertaining to stream channel morphometry (flow, alteration, and sinuosity) suggest that streams morphometry may be modified as part of the dam construction, maintenance and/or operation.

Reference streams were found to have better developed canopies than the experimental streams, which is reflective of the riparian zone that may be removed during construction of the impoundment. This again is suggested in the fact that there was a positive (and significant) relationship between canopy cover and age of impoundment so that the older the impoundment the more canopy cover.

The fact that both the extent of canopy and the overall habitat assessment score had positive relationships with age of dam construction indicates that there is some recovery of degraded habitat associated with time. This may also have some merit when considering biotic habitat. A recent study of impediments to fish migration in the Rappahannock River drainage (McIninch and Garman 1999) showed that fish communities are affected by dams and that biotic characteristics downstream of an impediment may exhibit some resilience over time. Dams of the Tidewater region of Virginia have a special significance because of their link to anadromous fishes. Garman and Macko (1998) showed that migratory fishes of Tidewater Virginia can supply an important nutrient input into the Coastal Plain ecosystem during their spring spawning runs. The stream reaches cut-off from these migrations are also isolated from the nutrient supply. Because, biological habitat components often mirror the degradation or restoration of the physical and chemical habitat parameters, it is important to consider both when directing management policy. Dam removal and the creation of fish passage at these impeded sites provide opportunities for the restoration of the stream ecosystem.

Some other aspects of this study warrant further consideration. A relatively small (but statistically valid) proportion of the impounded streams and reference conditions in Tidewater Virginia were analyzed. In addition to the impounded streams in the dam database, there are numerous agricultural dams and others that do not fit the conditions of this study. Also, data collection was limited seasonally to fall and winter months. Degradation of water quality may be most obvious during the summer months and although we did not observe significant alteration of water quality parameters in Tidewater, impacts associated with dams have been noted elsewhere (Ashby et al. 1999, Cassidy and Dunn, 1987). Some habitat characteristics such as extent of submerged aquatic vegetation are best analyzed during summer months. Species identification of grasses, shrubs and trees of the riparian zone is also most difficult during winter and late fall and was not attempted for this study. Others (Johnson and Brophy 1982; Malanson 1993) have noted species replacement and community alteration of riparian landscapes associated with dams. Our study examined more functional aspects of cover and bank vegetation and did not consider species interaction at the biotic level. Aspects of habitat upstream of the dam, most notably the drowned stream or river, were not considered during this study. Likewise, the effects of an instream barrier to movements of the biotic community were not considered by this study (but see McIninch and Garman 1999). Two particular examples are the upstream migration of anadromous fish species, mentioned above, and the potential that dams can hinder the recovery of biotic systems following a catastrophic event by cutting off access to a downstream colonization pool of species. Finally, it should be noted that impoundments located in the Piedmont, Ridge and Valley and Blue Ridge provinces are likely to interact with the downstream habitats differently than those of the Tidewater.

The habitat parameters found to be significantly different from reference conditions may present themselves as opportunities for restoration activity at two levels. Reduction of substrate scour will aid in the **instream** restoration of impacted sites and reduce sediment deposition rates. In addition, management practices to aid/restore **riparian** vegetation will help the canopy restoration.

The extent of degradation associated with channel alterations will be further examined during Phase II of this ongoing project. Phase II data will be collected for the analysis of habitat degradation associated with channelization and other forms of hydromodification. Once analyzed separately, those data will be combined with data from the present study for an inclusive hydromodification dataset and subsequent analysis.

Literature Cited

Ashby, S.L., J.L. Myers, E. Laney, D. Honnell and C. Owens. 1999. The effects of hydropower releases from Lake Texoma on downstream water quality. J. Freshwater Ecol. 14(1):103-112.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. Second edition. EPA 841-B-99-002. U.S. Environmental Protection agency, Office of Water, Washington D.C.

Cassidy, R.A. and P.E. Dunn. 1987. Water temperature control and areal oxygen consumption rates at a new reservoir, and the effects on the release waters. In: Craig, J.F. and J.B. Kemper (eds.). Regulated streams: advances in ecology. Plenum Press, New York.

Cohen, J. 1988. Statistical Power Analysis for the Behavioral Sciences 2nd. ed. Academic Press, New York.

Garman, G.C. and S. Macko. 1998. Contribution of marine-derived organic matter of an Atlantic coast, freshwater, tidal stream by anadromous clupeid fishes. J. North. Amer. Benth. Soc. 17(3):277-285.

George, D. and P. Mallery. 1999. SPSS for Windows Step by Step. A simple guide and reference. Allyn and Bacon, Boston.

Johnson, W.C. and J.A. Brophy. 1982. Altered hydrology of the Missouri River and its effects on floodplain forest ecosystems. Virginia Water Resources Res. Center Bull. 139. VPI&SU, Blacksburg.

Jongman, R.H.G., C.J.F. ter Braak, and O.F.R. van Tongeren (eds.). 1987. Data analysis in community and landscape ecology. Center for Agricultural Publishing and Documentation (Pudoc) Wageningen, the Netherlands.

Link, W.A., and J.S. Hatfield. 1990. Power calculations and model selection for trend analysis: a comment. Ecology 71:1217-1220.

Malanson, G.P. 1993. Riparian Landscapes. Cambridge University Press. Cambridge.

McIninch, S.P. and G.C. Garman. 1999. The anadromous clupeid fishes of the Chesapeake Bay. An evaluation of essential habitat and barriers to migration in the Rappahannock River basin. Final Project Report to VA Dept. Game & Inland Fisheries, Richmond, VA.

Sokal, R.R., and F.J. Rohlf. 1987. Introduction to Biostatistics, 2nd edition. Freeman and Co., New York.

Ter Braak, C.J.F. 1987-1992. CANOCO - a FORTRAN program for Canonical Community Ordination. Microcomputer Power, Ithaca, New York.

Table 1. Final study sites for Phase I of initial sampling (impediment review and habitat characterization).

Id No.	Impoundment	Location	Drainage
11901	Healeys Pond	Rte 629, Middlesex Co.	Piankatank
9709	Powers Dam	off Rte 685, King & Queen Co.	York
9703	Stolfi Dam	Rte 631, King & Queen Co.	York
10113	Herring Cr Millpond	Rte 607, King William Co.	York
3314	Campbells Millpond	Rte 601, Caroline Co.	York
19903	Waller Mill Res,	Rte 713, Williamsburg City	York
3303	Smoots Pond	Rte 640, Caroline Co.	York
3318	Elliots Pond	Rte 640, Caroline Co.	York
7303	Haynes Mill Dam	Rte 614, Gloucester Co.	York
19905	Jones Mill	Col. Pkwy, York Co.	York
11902	Barricks Millpond	Rte 625, Middlesex Co.	Rappahannock
8518	Forest Lk. Hills	Rte 900, Hanover Co.	York
9315	Smithfield Lk Dam	Rte 709, Isle of Wight Co.	James
8707	Ebhardt Dam	Rte 156, Henrico Co.	James
8501	Camp Hanover Dam	off Rte 609, Hanover Co.	York
12701	New Kent Lake	Rte 640, New Kent Co.	James
3901	Harrison Hatchery Lk	Rte 636, Charles City Co.	James
3323	Old Grays Dam	Rte 639, Caroline Co.	York
3306	White Lake	Rte 618, Caroline Co.	York
5707	Essex Millpond	Rte 609, Essex Co.	Rappahannock

Table 1 (cont.) Final study sites for Phase I of initial sampling

Id No.	Impoundment	Location	Drainage
5701	Hunters Millpond	Rte 637, Essex Co.	Rappahannock
15903	Mt. Airy Millpond	Rte 621, Richmond Co.	Rappahannock
19311	Chandlers Millpond	Rt 3, Westmoreland Co.	Rappahannock
3308	Gouldmans pond	off Rte. 17, Caroline Co.	Rappahannock
15303	Lake Montclair	off Rte 234, Prince William Co.	Potomac
14915	Jandls Dam	off Rte 156, Prince George Co.	Chowan
14911	Lake Binford	Rte 703, Prince George Co.	Chowan
14905	Manns Dan	Rte. 658, Prince George Co.	James
15306	Lake Jackson	Rte 234, Prince William Co.	Potomac
4104	Swift Creek Dam	off Rte 780, Chesterfield Co.	James
5902	Burke Lake	Rte 123, Fairfax Co.	Potomac
15308	Camp 5 Dam	off Rte 619, Prince William Co.	Potomac
Control 1	Powells Creek	Rte 643, Prince William Co.	Potomac
Control 2	Bailey Branch	Rte 613, Surry Co.	James
Control 3	Powell Creek	Rte 666, Prince George Co.	James
Control 4	Polecat Creek	Rte 207, Caroline Co.	York
Control 5	Richardson Creek	Rte 614, Richmond Co.	Rappahannock
Control 6	Pantico Run	Rte. 690, Westmoreland Co.	Rappahannock
Control 7	Dragon Run	Rte. 607, Essex Co.	Piankatank
Control 8	Horse Swamp	Rte 614, Isle of Wight	Chowan
Control 9	Reedy Creek	Rte. 745, Chesterfield Co.	James
Control 10	West Run of Henry Cr	Rte 625, Charles City Co.	James

Table 2 Correlation coefficients of habitat variables with values for the first two axes from the canonical correspondence analysis. Parentheses indicate cumulative percentage variance of site-habitat relation explained by the CCA. Dashes are used instead of numbers when relationship is nonsignificant.

Environmental Variable	CCA1	CCA2
	(82.7)	(86.0)
A		
Riparian Veg. (right bank)	0.609	0.149
Sand Substrate	0.574	--
Silt Substrate	0.468	--
Detritus on Substrate	0.431	--
Riparian Veg. (left bank)	0.390	--
Canopy Cover	0.385	--
Stream Width	-0.607	-0.246
Link	-0.570	-0.214
Gravel Substrate	-0.500	--
Turbidity	-0.481	--
Run habitat	--	0.330
Percent Dlink	--	0.191
pH	--	-0.371
Pool variability	--	-0.305
Stream depth	--	-0.245

Table 3. Results of Independent Samples t-tests of habitat data from dam sites (experimental group) and reference sites (control group). ** Indicates statistically significant differences between experimental and control groups (P<0.05).

Parameters	Units	Equal Variance	df	Sig.
Temperature	^{O}C	Yes	40	.341
Turbidity	NTU	Yes	40	.814
pH		Yes	40	.996
Dissolved Oxygen	mg/L	Yes	40	.462
Conductivity	µS/cm	Yes	40	.797
Flow	m/sec	Yes	40	.691
Depth	Centimeters	Yes	40	.547
Width	Meters	Yes	40	.115
Riffle Habitat	Percent of 100m	Yes	40	.757
Run Habitat	Percent of 100m	No	40	.155
Pool Habitat	Percent of 100m	Yes	40	.200
Canopy	Percent of 100m	yes	40	.006**
Cobble Substrate	Percent of 100m	Yes	40	.459
Gravel Substrate	Percent of 100m	Yes	40	.099
Sand Substrate	Percent of 100m	Yes	40	.031**
Silt Substrate	Percent of 100m	Yes	40	.101
Clay Substrate	Percent of 100m	No	40	.120
Detritus Present	Percent of 100m	Yes	40	.259
Muck Present	Percent of 100m	Yes	40	.633
Marl Present	Percent of 100m	No	40	.022**
Epifaunal Substrate	Scored over 100m	No	40	.115
Pool Substrate	Scored over 100m	No	40	.379
Pool Variability	Scored over 100m	No	40	.001**
Sediment Deposit.	Scored over 100m	No	40	.001**
Channel Flow	Scored over 100m	No	40	.001**
Channel Alteration	Scored over 100m	No	40	.011**
Channel Sinuosity	Scored over 100m	No	40	.034**
Bank Stability (L)	Scored over 100m	No	40	.051
Bank Stability (R)	Scored over 100m	No	40	.080
Bank Veget. (L)	Scored over 100m	No	40	.237
Bank Veget. (R)	Scored over 100m	No	40	.070
Riparian Veg. (L)	Scored over 100m	No	40	.026**
Riparian Veg. (R)	Scored over 100m	No	40	.026**
Total Assess. Score	Calculated	No	40	.001**

Table 4 Results of comparative analysis for classes of dam. Linear regression and Kruskal-Wallace nonparametric tests of habitat data. ** indicates a statistically significant difference between experimental and control groups (P<0.05).

Parameters	Age	Height	Capacity	Class
Temperature	----	----	----	----
Turbidity	----	----	----	----
pH	----	----	----	----
Dissolved Oxygen	----	----	----	----
Conductivity	----	----	----	----
Flow	----	----	----	----
Depth	----	----	----	----
Width	----	----	----	----
Riffle Habitat	----	----	----	----
Run Habitat	----	----	----	----
Pool Habitat	----	----	----	----
Canopy	.002** (+)	.001** (-)	----	----
Cobble Substrate	----	----	----	----
Gravel Substrate	----	----	----	----
Sand Substrate	----	----	----	----
Silt Substrate	----	----	----	----
Clay Substrate	----	----	----	----
Detritus Present	----	----	----	----
Muck Present	----	----	----	----
Marl Present	----	----	----	----
Epifaunal Substrate	----	----	----	----
Pool Substrate	----	----	----	----
Pool Variability	----	----	----	----
Sediment Deposit.	----	----	----	----
Channel Flow	----	----	----	----
Channel Alteration	----	----	----	----
Channel Sinuosity	----	----	----	----
Bank Stability (L)	----	----	----	----
Bank Stability (R)	----	----	----	----
Bank Veget. (L)	----	----	----	----
Bank Veget. (R)	----	----	----	----
Riparian Veg. (L)	----	----	----	----
Riparian Veg. (R)	----	----	----	----
Total Assess. Score	.001**	----	----	----

Figure 1. Sample rapid habitat assessment sheets used to evaluate instream and riparian habitat conditions.

Figure 2. Additional field habitat sheets used for the evaluation of habitat parameters.

Figure 3. First and second axes from the canonical correspondence analysis of sites and habitat parameters from Tidewater, Virginia. Dots represent sites. Numbers are Virginia dam codes. Sites are grouped by major drainage.

Figure 4. First and second axes from the canonical correspondence analysis of sites and habitat parameters from Tidewater, Virginia. Dots represent sites. Numbers are Virginia dam codes. Sites are grouped by year of dam construction.

Figure 5. First and second axes from the canonical correspondence analysis of sites and habitat parameters from Tidewater, Virginia. Dots represent sites. Numbers are Virginia dam codes. Sites are grouped by height of dam categories (ex/ 5-15 feet).

Figure 6. First and second axes from the canonical correspondence analysis of sites and habitat parameters from Tidewater, Virginia. Dots represent sites. Numbers are Virginia dam codes. Sites are grouped by impoundment capacity (total) categories. Numbers are given in acre-feet.

Figure 7. First and second axes from the canonical correspondence analysis of sites and habitat parameters from Tidewater, Virginia. Dots represent sites. Numbers are Virginia dam codes. Sites are grouped by class.

Appendix I. Chapter of 5 of Barbour et al. 1999. Description of methodology for rapid habitat assessment.

Appendix II. Data dictionary for dam database, Excel spreadsheet.

DATA DICTIONARY
DAMS INVENTORY DATA BASE

FIELD No.	Name, Type & Size	**DESCRIPTION**
1	F (N,3)	Official Virginia FIPS Code designation for county or city in which dam is located. See code.
2	I_NO (C,5)	Official Virginia identification number. The first three digits are to be the same as the FIPS Code. This number is the unique identifier for each dam and is not repeated within the database. All numbers are to be assigned by the data administrator.
3	R_N (C,1)	Use R for regulated dam or N for non-regulated, as defined by the VDSR,
4	NAME-DAM (C,37)	Official name of dam as determined by owner.
5	OTHERNAME (C,37)	Optional names. Leave blank if not applicable.
6	OWNER_NAME (C,37)	Name of owner. Include the term SWCD somewhere within this field if dam is owner by a Soil and Water Conservation District. Include the term (S) if dam is SCS-assisted project dam but Owned by a District.
7	STREET_POB (C,37)	Street address of owner.
8	CITY_ST_ZC (C,37)	City, state, and postal zip code for owner.
9	PHONE_NO (C,13)	Phone number of owner. Include area code.
10	CLASS (N,1)	Official class as determined by Director. Use 1,2,3,or 4.
11	CERT_TYPE (C,2)	Use one of the following codes if regulated dam: MR for regular operation and maintenance certificate MC for conditional certificate MF for Class 4 Use one of the following codes if non-regulated dam: SE for size exemption AE for agricultural exemption ME for mining exemption FL for Federal license of Federal ownership.

Note: Newly constructed dams are not to be added to the data base until a construction permit is issued. When a permit is

		issued for a new dam, the designation CO is entered in PMT_TYPE but CERT_TYPE remains blank until a certificate (MC,MR, or MF) is issued. Newly found, existing dams should be added and field CERT_TYPE left blank until one of the above designations is determined.
12	CERT_DATE (D,8)	For regulated dams, use date of latest certificate for CERT_TYPE. For non-regulated dams, use date of determination of exemption.
13	PMT_TYPE (C,2)	CO for construction permit. AL for alteration permit. Note: Newly constructed dams are not to be added to the data base until a construction permit is issued.
14	PMT_DATE (D,8)	Date of approval for PMT_TYPE.
15	EXT_TO (D,8)	Date for extension of either CERT_TYPE or PMT_TYPE.
16	EAP (C,2)	Y for yes if a current EAP exists. N for no if none is known to exist NR for not required if an EAP is not required.
17	EAP_DATE (D,8)	Date for EAP (Optional field.)
18	TOT_HT (N,5.1)	The vertical distance in feet as measured from the natural bed of the stream or water course at the downstream toe of the dam to the top of the dam. (Official height as defined by Virginia Dam Safety Regulations and used for determining applicability of Virginia Dam Safety Act).
19	TOT_CAP (N,7)	The volume in acre-feet that is capable of being impounded at the top of the impounding structure. (Official storage as defined by Virginia Dam Safety Regulations and used for determining applicability of Virginia Dam Safety Act).
20	NOR_CAP (N,10)	The volume in acre-feet that is capable of being impounded at the elevation of the crest of the lowest ungated outlet.
21	NOR_AREA (N,10)	Surface area, in acres, of the impoundment at its normal retention level

22	DAMLENGTH (N,10)	Length of dam in feet defined as: length along top of dam. This also includes the spillway, powerplant, navigation lock, fish pass, etc., where these form part of the length of the dam. If detached from the dam, these structures should not be included.
23	OWNER_TYPE (C,1)	Owner type using following code: F for Federal U for Public Utility S for State P for Private L for Local Government D for District
24	NONFED (C,1)	Code to indicate private dam on Federal property: Y for Yes N FOR No
25	RIVER (C,30)	River or stream upon which dam is located. Tributary can be noted as Trib.
26	YR_COMP (N,4)	The year when the main dam structure was completed. If dam had a major modification use that date.
27	TERTY_NO (C,3)	Territory number in which the dam is located.
28	ENGRG_NO (N,3)	The personnel position number of the dam safety engineer to which the dam is assigned.
29	PH1_RPT (C,1)	Code indicating whether the dam was inspected in the Phase I Inspection Program, National Program of Inspection of Non-Federal Dams (92-367). Use the code: Y for Yes N for No; Leave blank if unknown.
30	LAST_VISIT (D,8)	Date of latest field visit to the dam by the assigned dam safety engineer.
31	ACMP_BY (C,2)	Enter code based on who accompanied dam safety engineer on LAST_VISIT: O for owner E for owner's engineer OE if accompanied by both the owner and the owner's engineer. Leave blank if dam safety engineer visited site with neither.
32	INS_RCD_O (D,8)	Enter date of inspection for the most recent owner's inspection report received.
33	INS_RCD_E (D,8)	Date of inspection for the most recent owner's inspection report received. For certificate, recertification, or conversion to regular certificate, of Class 1,2 or 3 dam, use date of engineer's inspection used as the basis for the certificate. For class 4 dams, field is normally blank.

34 QUAD (C,4) — Code for USGS Quad sheet on which dam is located. See index on wall in Dam Safety Section.

35 LAT (C,7) — Latitude of dam expressed as degrees, minutes, and tenths. For example 36-22.7.

36 LNG (C,7) — Longitude of dam expressed as degrees, minutes, and tenths. For example, 82-22.7.

37 DA_SM (N,7.2) — Drainage area of dam expressed in square miles and defined as the total area that drains to the dam on a river or stream.

38 TYPE (C,2) — Enter one code that most nearly indicates the type of dam.

RE for Earth	CN for Concrete
ER for Rockfill	MS for Masonry
PG for Gravity	ST for Stone
CB for Buttress	TC for Timber Crib
MV for Multi-Arch	VA for Arch
RR for Roller Compacted	OT for Other

39 PURPOSE (C,4) — One to four codes listed in priority order to indicate purpose for which reservoir is used.

I for irrigation	H for Hydro-electric
C for flood control or storm water management	
S for water Supply	R for Recreation
P for Fire Protection	F for Fish & Wildlife or small farm pond.
D for Debris Control	T for Tailings
O for Other	

40 SDF_R (C,7) — The required spillway capacity of the dam as required by the Virginia Dam Safety Regulations. If a value less than that shown in Table I is allowed by use of Section 3.4, use the lesser value. Express as a frequency or as a percentage of PMF. For example 50 PMF, or 88% PMF.

41 SDF_A (C,7) — The available spillway capacity of the dam as determined at the maximum design high water. Express as a frequency or as a percentage of PMF. For example 100 YR, PMF, or 88% PMF.

42 NATIONALID (C,7) — The National ID of the dam if assigned at the time of the 1981 Corps of Engineers Inventory. Optional Field.

43 COUNTY (C,30) — Name of county or city in which dam is located.

44	NCITY (C,30)	Name of nearest city or community that is most likely to be affected by floods resulting from dam failure.
45	DIST_CITY (N,4.2)	Distance from dam to NCITY (miles).
46	DOW_HAZ (C,1)	Hazard classification from Corps of Engineers 1981 inventory data (Optional Field). L for Low, S for Significant, H for High Blank if not available.
47	ES_HT (N, 10.2)	Dam height as indicated in the 1981 COE data. Optional field.
48	PS_HT (N, 10.2)	Structural height of dam as indicated in the 1981 COE data. Optional field.
49	NP_HT (N,10.2)	Hydraulic height of dam as indicated in the 1981 COE data. Optional field.
50	MAX_Q (N,10.2)	Discharge capacity in cfs of the spillway at the maximum designed water surface elevation. Optional field.
51	TOT_AREA (N,10.2)	Surface area, in acres, of the impoundment at the top of dam elevation.
52	MEMO (M,10)	MEMO field optional for adding any comments which can be retained as permanent record.
53	COMMENTS (C,35)	Optional field to add any pertinent comments.
54.	I_NO (C,5)	Official Virginia identification number. The first three digits are to be the same as the FIPS Code. This number is the unique identifier for each dam and is not repeated within the database. All numbers are to be assigned by the data administrator.